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Energy parameters of construction elements in the passive house concept

Parametrii energetici ai elementelor de construcție în conceptul de casă pasivă

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Abstract. *Newly built houses are subject to requirements with high levels of energy performance including the creation of houses with zero energy consumption (passive houses) and respectively without carbon emissions. Building regulations, processes and control will need to be rethought in light of these ambitions and a development of performance guarantees in the construction sector.Many mandatory standards and rating systems for the energy efficiency of buildings have been developed globally, but those for passive houses are still voluntary, and for this reason there is little data on the performance of houses built to these standards. They have emerged as a promising approach to mitigating and solving many energy problems, and constructive visions and solutions and testing or demonstrating their feasibility are undoubtedly major steps in the process of solving the energy problem.*

Key words: *passive house, energy parameters, performance of materials, operational costs*

1. Introduction

This article studies the influence of energy parameters in building materials for the certification of passive houses. Through a case study, the influence of building insulation on consumption and building operating costs is presented according to the performance of insulating materials, emphasizing comparisons between consumption and operating costs according to the type of insulation.

2. The influence of building insulation on the consumption and operating costs of construction materials

The most important aspect of an insulation material is its performance to consistently ensure resistance to heat transfer throughout the life of the building. Although performance expectations given by the manufacturer are essential, other factors associated with the "real" installation of the material must be considered as part of the design process, namely [1]:

- ease of installation - final performance will be determined by how efficiently a builder can install a material using conventional skills. For example, insulation boards must be installed so that there are no gaps either between adjacent boards or between the boards and other building components that are part of the overall insulation envelope, such as rafters or joists. Any remaining gaps will allow air to pass through and result in reduced performance.

- shrinkage, compaction, settlement - some materials may experience some degree of dimensional instability during installation. In many cases this is anticipated and can be overcome by careful design and installation methods. In all other cases, the builder should seek guidance from the insulation manufacturer regarding the associated risks, particularly where the materials have not performed stably at installation.

– humidity protection - some insulating materials suffer performance degradation when they are wet. The designer must, through technical details, ensure that the vulnerable insulation is protected from humidity. If humidity is at high risk (penetration or above 95% RH), then a resistant material should be chosen.

3. Consumption and operating costs of buildings depending on the type of insulation. Comparative study

The calculation was made using the Hydrolution program provided by Mitsubishi Heavy Industries [2]. For the analyzed building, a hot water consumption of 45 l/day/person was considered. The conventional external calculation temperature for the chosen town of Lugoj is -12 ^{o}C and as equipment we chose an air-water heat pump in parallel with an electric boiler. In the following, the simulations performed for each of the insulation materials analyzed (mineral glass wool, polyurethane foam and straw) are analyzed:

-Mineral glass wool [2]

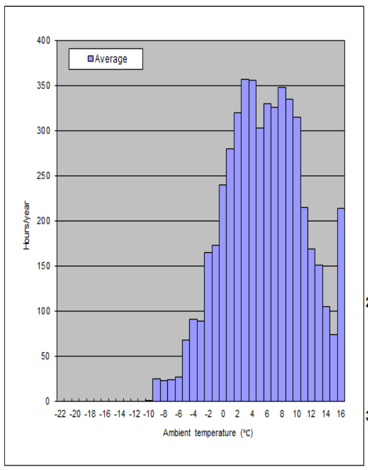
Made from fused glass, typically with 20% to 30% recycled industrial waste and post-consumer content. The material consists of glass fibers arranged using a binder in a wool-like texture. The process traps many small air pockets between the glass, and these small air pockets result in high thermal insulation properties. The density of the material can be varied by pressure and binder content (Fig. 1).

- Thermal conductivity / λ , W / m^2 K = 0,035;
- Thermal resistance at 100mm K m^2/ W = 2,85;

- Specific heat capacity J / (kg. K) = 1030;
- Density kg / m^3 = circa 20;
- Thermal diffusivity m^2/ s = 0,0000016;
- Built-in energy MJ / kg = 26;
- Vapor permeable: Yes.

1. Heat load estimation

Climate zone	Average	Choose from drop-down Cold: Helsinki Average: Strasbourg Warm: Athens custom Custom2 Custom3



Calculation type	2		Choose from drop-down 1: Current boiler energy consumption 2: Floor area and insulation quality 3: Design temp and capacity
Input for Calc type 1			
Conventional Boiler type	Electricity		Choose from drop-down Gas/ Oil/ Electricity *Default efficiency applies.
Annual energy consumption	16500	kWh/year	Input value
Design temperature	-10	°C	Auto indication
Refer to Default setting sheet for unit conversion for gas and oil.			
Input for Calc type 2			
Floor area	150	m2	Input value
Q value (Insulation quality)	0.035	W/(m2·K)	Input value
Design temperature	-10	°C	Auto indication
※Q-value is unit heat load per 1sqm floor area and 1K temperature difference			
Input for Calc type 3			
Design temperature	-15	°C	Input value *Possible lowest temperature applies if blank
	8		
Capacity at design temp	16	kW	Input value

2. HW load estimation

HW supply	Yes		Choose from drop-down Yes/ No
Input one of those conditions			
Hot water supply volume	120	L/day	Input daily HW consumption or number of people living in the premises
Number of people			

3. Estimated required heat load

Annual heating load	282	kWh/year	Auto indication
Annual hot water load	1783	kWh/year	Auto indication
Annual total load	2064	kWh/year	Auto indication

Fig.1. Vitrified mineral wool input data

For a thermal conductivity value of 0.035 W/m^2 K, an annual requirement of 2064 kWh/year results.

Annual energy consumption of the heat pump compared to the electric boiler (Fig. 2).

1. Capacity selection of Hydrolution

Model	FDCW71VNX-A	Choose from drop-down FDCW71VNX/100VNX/140VNX
Heating water temperature	55 °C	Choose from drop-down 35/45/55°C
Internal heater use	No	Choose from drop-down Yes/No
External heat source	Electricity	Choose from drop-down Gas/ Oil/ Electricity *Default efficiency applies.

2. Required capacity

Required Annual capacity	2064	kWh/year
Covered by Heat Pump:	2064	kWh/year
Covered by Internal heater:	0	kWh/year
Covered by External heat source:	0	kWh/year
(Hot water capacity included in the above:	120	L/day)
Required capacity at -10 °C:	0.3	kW
Covered by Heat Pump:	0.3	kW
Covered by Internal heater:	0.0	kW
Covered by External heat source:	0.0	kW

3. Annual energy consumption

Annual energy consumption of Hydrolution:

Heat Pump:	810	kWh/year	(Electricity)
Internal heater:	0	kWh/year	(Electricity)
External heat source:	0	kWh/year	(Electricity)

4. Comparison of annual energy consumption

Annual energy consumption of alternative boiler:	2401	kWh/year	(Electricity)
Boiler type	Electricity		Choose from drop-down Gas/ Oil/ Electricity
Efficiency	86%		Input value(0-100%) (Default value applies if blank)

Fig. 2. Energy consumption (glass wool)

Depending on these annual consumptions, the comparison of costs and the time in which the air-to-water heat pump amortizes its investment results (Fig. 3).

Life time cost comparison

Hydrolution	**FDCW71VNX-A**		**Alternative Boiler**		
1. Initial Cost					
Equipment	6500	EUR	Equipment	1500	EUR
Installation	2000	EUR	Installation	2000	EUR
2. Running Cost					
Maintenance cost	500	EUR/year		1200	EUR/year
Night time operation ratio	75%	Input value (0-100%)			
Annual energy cost					
Electricity	60.7	EUR/year	Gas	0.0	EUR/year
Gas		EUR/year	Oil		EUR/year
Oil		EUR/year	Electricity	360.1	EUR/year
Total	60.7	EUR/year	Total	360.1	EUR/year

Payback Time **5.0 years**

Fig. 3. Costs (mineral wool)

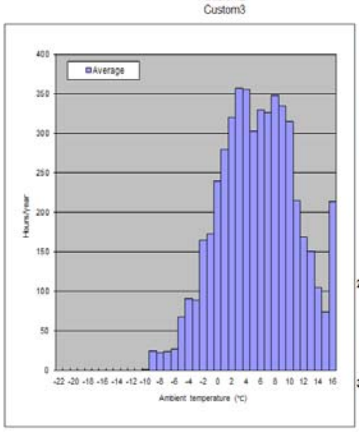
- ***Polyurethane foam*** [2]

Polyurethane (PUR and PU) is a polymer composed of organic units joined by carbamate (urethane) bonds. Polyurethane can be manufactured in a variety of densities and hardnesses by varying the isocyanate, polyol or additives (Fig. 4).

- Thermal conductivity / λ (lambda) W / m. K = 0,023-0,026;
- Thermal resistance at 100mm K m^2/ W = 4,50;
- Specific heat capacity J / (kg. K) = n / a;
- Density kg / m^3 = 30 – 40;
- Thermal diffusivity m/ s = n / a;
- Built-in energy MJ / kg = 101;
- Vapor permeable: No.

1. Heat load estimation

Climate zone	Average	Choose from drop-down Cold: Helsinki Average: Strasbourg Warm: Athens custom Custom2 Custom3



Calculation type	2		Choose from drop-down 1: Current boiler energy consumption 2: Floor area and insulation quality 3: Design temp and capacity
Input for Calc type 1			
Conventional Boiler type	Electricity		Choose from drop-down Gas/ Oil/ Electricity *Default efficiency applies.
Annual energy consumption	16500	kWh/year	Input value
Design temperature	-10	°C	Auto indication
Refer to Default setting sheet for unit conversion for gas and oil			
Input for Calc type 2			
Floor area	150	m2	Input value
Q value (Insulation quality)	0.023	W/(m2·K)	Input value
Design temperature	-10	°C	Auto indication
※Q-value is unit heat load per 1sqm floor area and 1K temperature difference			
Input for Calc type 3			
Design temperature	-15	°C	Input value *Possible lowest temperature applies if blank
	8		
Capacity at design temp	16	kW	Input value
2. HW load estimation			
HW supply	Yes		Choose from drop-down Yes/ No
Input one of those conditions			
Hot water supply volume	120	L/day	Input daily HW consumption or number of people living in the premises
Number of people			
3. Estimated required heat load			
Annual heating load	**185**	kWh/year	Auto indication
Annual hot water load	**1783**	kWh/year	Auto indication
Annual total load	**1968**	kWh/year	Auto indication

Fig. 4. Polyurethane foam (input data)

For a thermal conductivity value of 0.023 W/m^2 K, an annual requirement of 1968 kWh/year results.

The annual energy consumption of the heat pump compared to the electric power plant (Fig. 5).

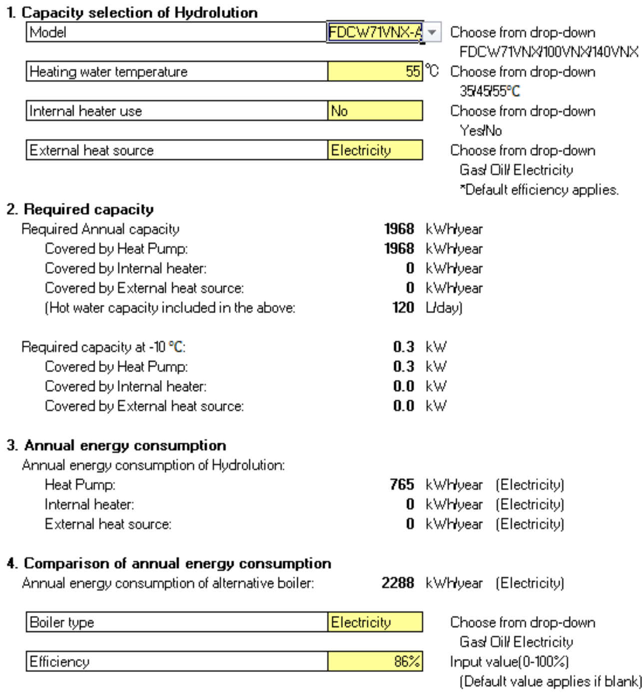


Fig. 5. Annual consumption (polyurethane foam)

Cost comparison and the time in which the air-to-water heat pump amortizes its investment (Fig. 6).

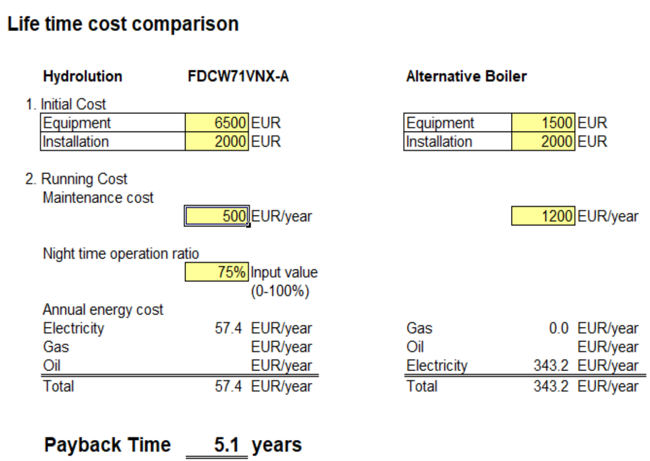


Fig. 6. Costs (polyurethane foam)

- Straw [2]

Straw is an agricultural by-product, the dried stalks of cereal plants after the grain and chaff have been removed.

Straw accounts for about half of the yield of cereal crops such as barley, oats, rice, rye and wheat (Fig. 7).

- Thermal conductivity / λ (lambda) W / m. K = 0,08 (for load-bearing structures);
- Thermal resistance at 350mm K m^2/ W = 4,37 la 350mm;
- Specific heat capacity J / (kg. K) = unavailable;
- Density kg / m^3= 110 – 130;
- Thermal diffusivity m^2/ s = unavailable;
- Built-in energy MJ / kg = 0,91 (source ICE database 2011);
- Vapor permeable: Yes.

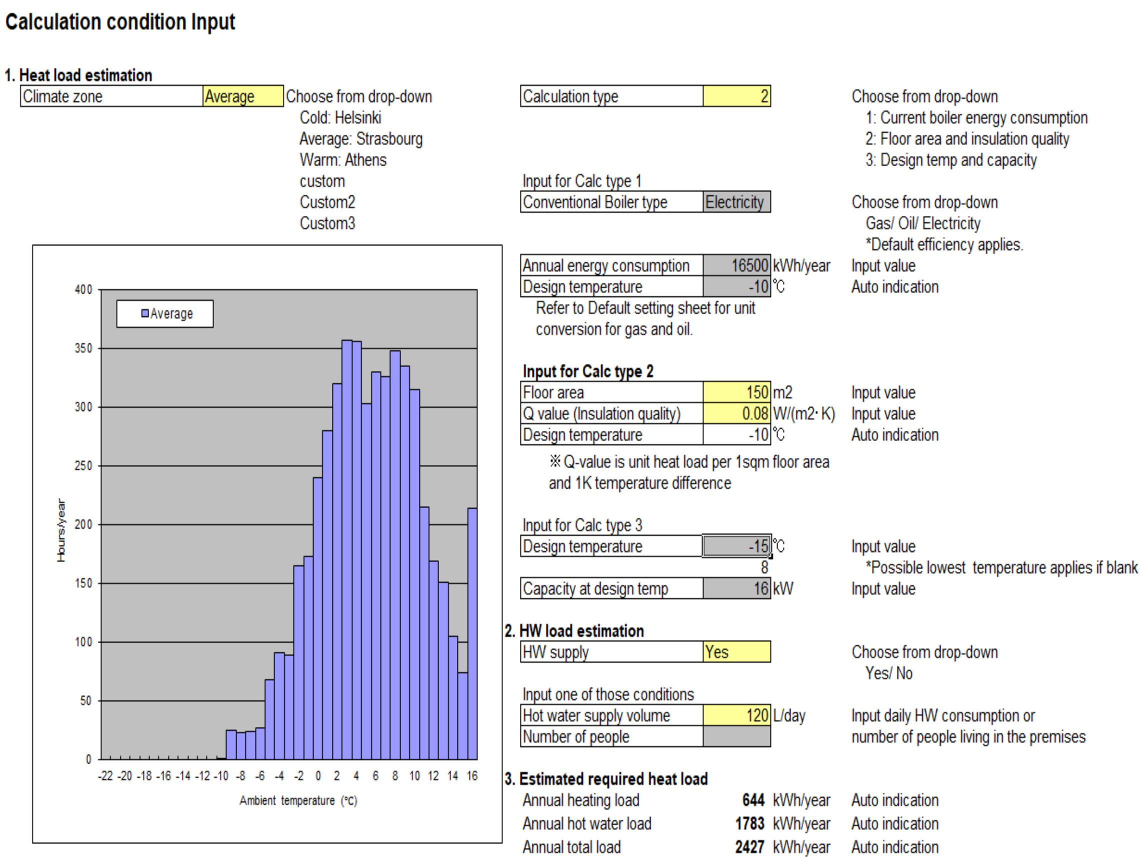


Fig. 7. Straw input data

For a thermal conductivity value of 0.08 W/m^2 K, an annual requirement of 2427 kWh/year results.

The annual energy consumption of the heat pump compared to the electric power plant (Fig. 8).

1. Capacity selection of Hydrolution

Model	FDCW71VNX-A		Choose from drop-down FDCW71VNX/100VNX/140VNX
Heating water temperature	55	°C	Choose from drop-down 35/45/55°C
Internal heater use	No		Choose from drop-down Yes/No
External heat source	Electricity		Choose from drop-down Gas/ Oil/ Electricity *Default efficiency applies.

2. Required capacity

Required Annual capacity	2427	kWh/year	
Covered by Heat Pump:	2427	kWh/year	
Covered by Internal heater:	0	kWh/year	
Covered by External heat source:	0	kWh/year	
(Hot water capacity included in the above:	120	L/day)	
Required capacity at -10 °C:	0.5	kW	
Covered by Heat Pump:	0.5	kW	
Covered by Internal heater:	0.0	kW	
Covered by External heat source:	0.0	kW	

3. Annual energy consumption

Annual energy consumption of Hydrolution:

Heat Pump:	977	kWh/year	(Electricity)
Internal heater:	0	kWh/year	(Electricity)
External heat source:	0	kWh/year	(Electricity)

4. Comparison of annual energy consumption

Annual energy consumption of alternative boiler:	2822	kWh/year	(Electricity)
Boiler type	Electricity		Choose from drop-down Gas/ Oil/ Electricity
Efficiency	86%		Input value(0-100%) (Default value applies if blank)

Fig. 8. Consumables (straw)

Cost comparison and the time in which the air-to-water heat pump amortizes its investment (Fig. 9).

Life time cost comparison

Hydrolution	FDCW71VNX-A		Alternative Boiler		
1. Initial Cost					
Equipment	6500	EUR	Equipment	1500	EUR
Installation	2000	EUR	Installation	2000	EUR
2. Running Cost					
Maintenance cost	500	EUR/year		1200	EUR/year
Night time operation ratio	75%	Input value (0-100%)			
Annual energy cost					
Electricity	73.3	EUR/year	Gas	0.0	EUR/year
Gas		EUR/year	Oil		EUR/year
Oil		EUR/year	Electricity	423.3	EUR/year
Total	73.3	EUR/year	Total	423.3	EUR/year

Payback Time 4.8 years

Fig. 9. Costs (straw)

4. Concluzii

Following these comparisons, we observe how and how much consumption varies depending on the type of insulation chosen, this is just one factor, quite important in fact, in the process of designing and building an energy passive building. The tightness of the buildings was evaluated in terms of hourly air changes. The hourly exchange rate at 50 Pa is n50 = 0.2 air exchanges/h. The reference building is not equipped with window shades. Solar4S + Low-e6 + Clear triple pane windows were chosen for the windows, with "U" coefficient values of 0.6 W/m^2K, resulting in a thermal resistance R of 1.66 m^2K/W.

References

[1] Agoria, „EPB policy framework: an introduction into the measure and the ongoing discussions", in Buildings-Climateneutral, comfortable and secure (re)construction, 07 February, 2020.
[2] Mitsubishi Heavy Industries, „Hydrolution program provided", 2022.